Models for Estimation of Chemical Distribution and Fate in Response to Remedial Alternatives in the Lower Willamette River

Technical Briefing
Portland Harbor Superfund Project

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Purpose

- Evaluate impact of source control activities and remedial action alternatives on chemical levels in:
  - Sediment and water
  - Fish
- Provide estimates (by segment) of:
  - Loads from external sources
  - Ambient levels in relation to PRGs
  - Probability of site recontamination
  - Contributions from outside the site (e.g., upstream)
  - Effects of monitored natural recovery
  - Downstream responses to actions upstream

Response to remedial actions

- **How much?** Source reductions may not translate into a proportional reduction in sediment, water, fish
- **How fast?** Temporal response of system will depend on which source is targeted for remediation
- **How permanent?** If ultimate source is not remediated, potential for recontamination will remain
- **How extensive (spatially)?** Downstream extent of response depends on both biological and physical processes
- **How necessary?** Considering the role of “natural” attenuation in load reduction

A decision support tool

- A computer model, in conjunction with data analyses, may be used to quantitatively and comparatively address these primary study questions
- Use of a model may decrease uncertainty in effectiveness of the preferred remedy
- Benefits
  - Constrain, synthesize and interpret data
  - Compare remedial alternatives on same basis
- Drawbacks
  - Level of uncertainty in results may be unacceptable

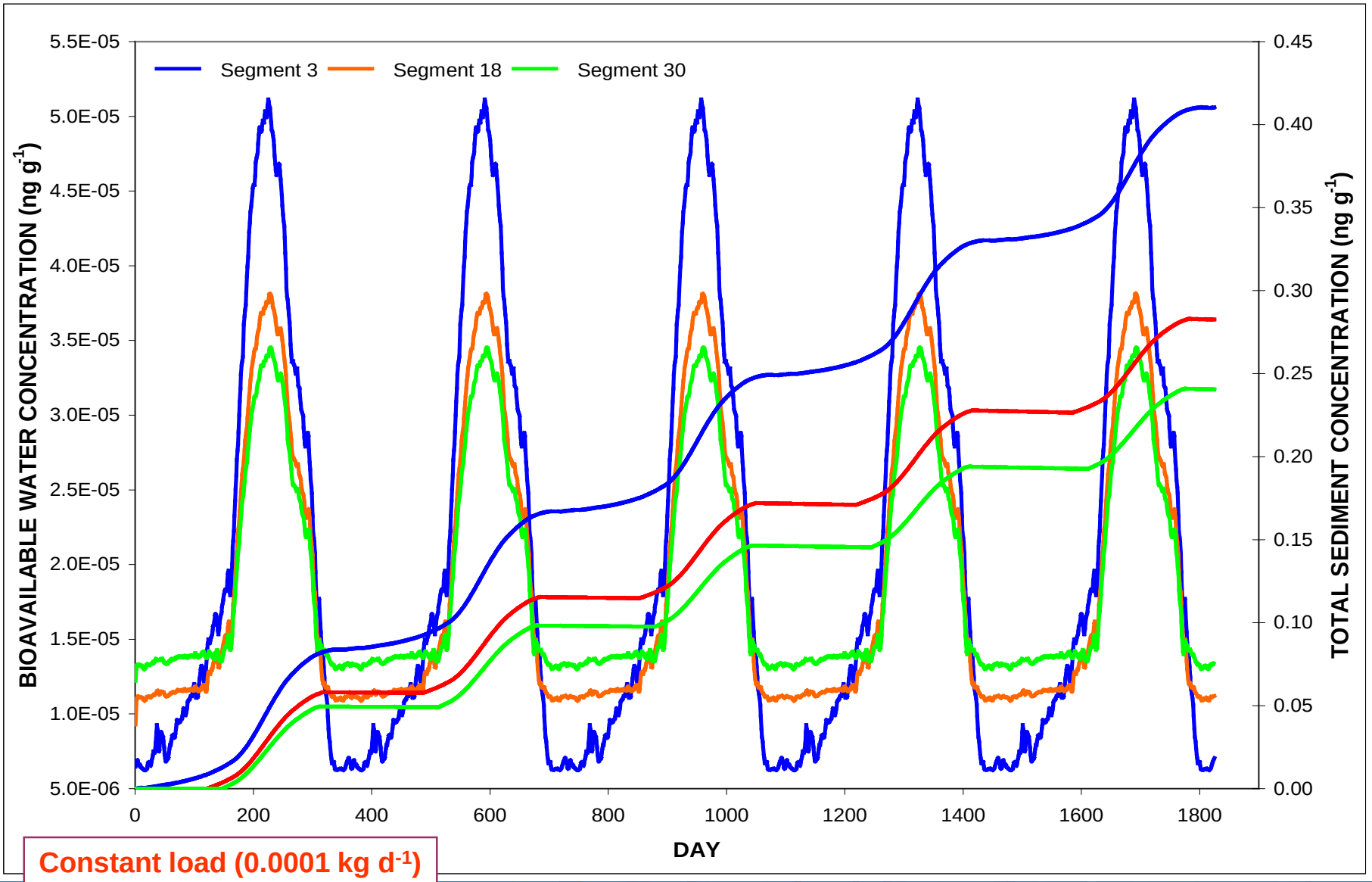
Key specifications

- TRANSPARENCY
- Link transport & fate ⇨ food web models
- Incorporate spatial variability
  - Exposure of mobile species
- Incorporate temporal variability
  - Seasonal variation; Non-steady-state dynamics
- Evaluate organics and other chemicals
- Results as mass or concentration
- Food web-specific:
  - Invertebrates as whole animals, intra- and up-trophic consumption, model fish ⇨ bird ⇨ egg

Concept

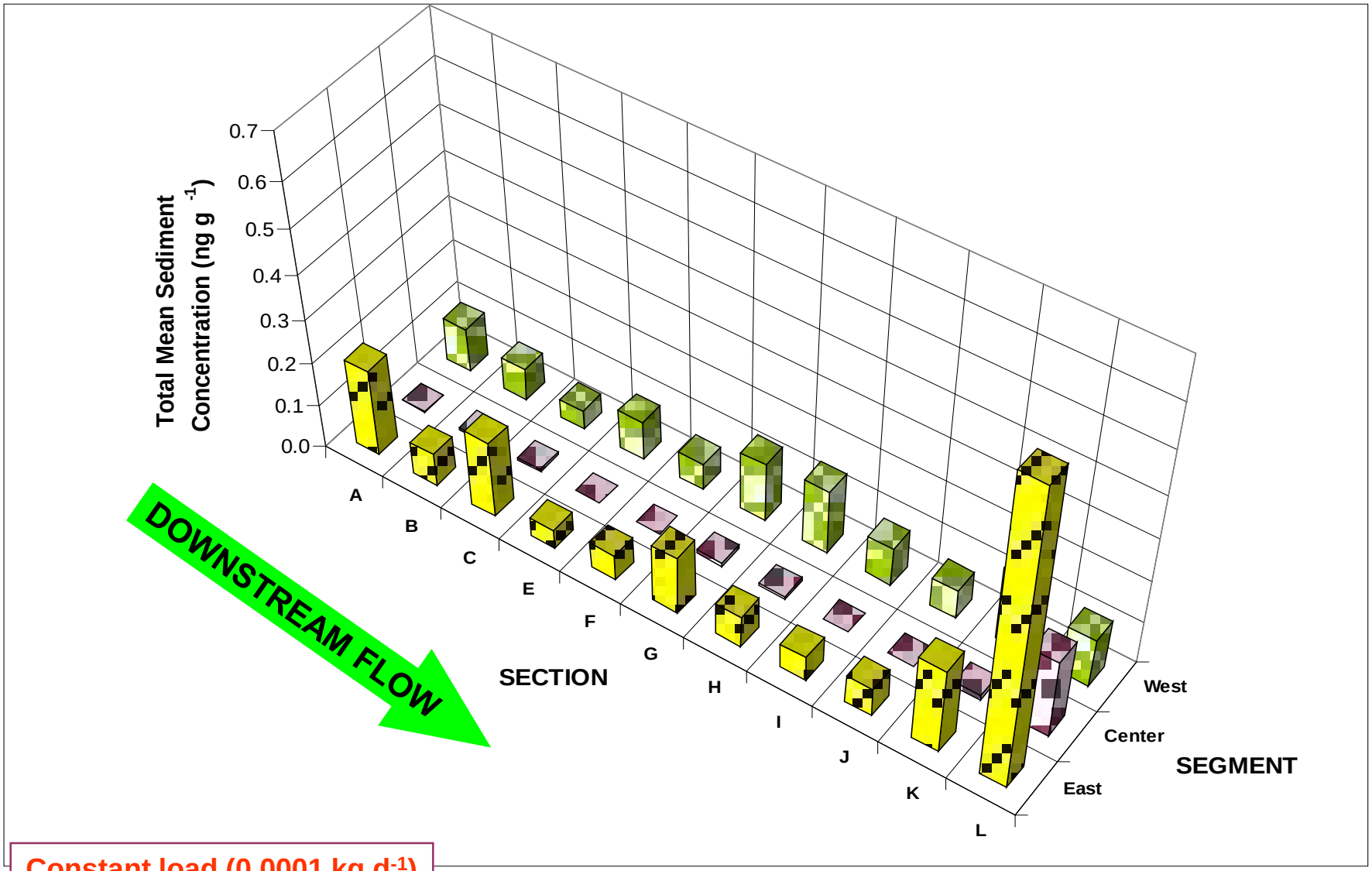
- Linked biotic and abiotic sub-models
  - After Gobas et al. (1998) - Fraser River
- Abiotic - transport & fate sub-model
  - After Davis (2003, 2004) for San Francisco Bay
  - Considers back- and cross-flows between segments
  - STELLA®
- Biotic - food web sub-model
  - After Arnot & Gobas (2004)
  - Same generic structure in every segment
    - Multi-segment exposure for mobile species
    - Excel® & Visual Basic®

Changes in water & sediment concentrations



Constant load (0.0001 kg d^{-1}) to water in segments 1,2,3

Changes in sediment concentration across segments



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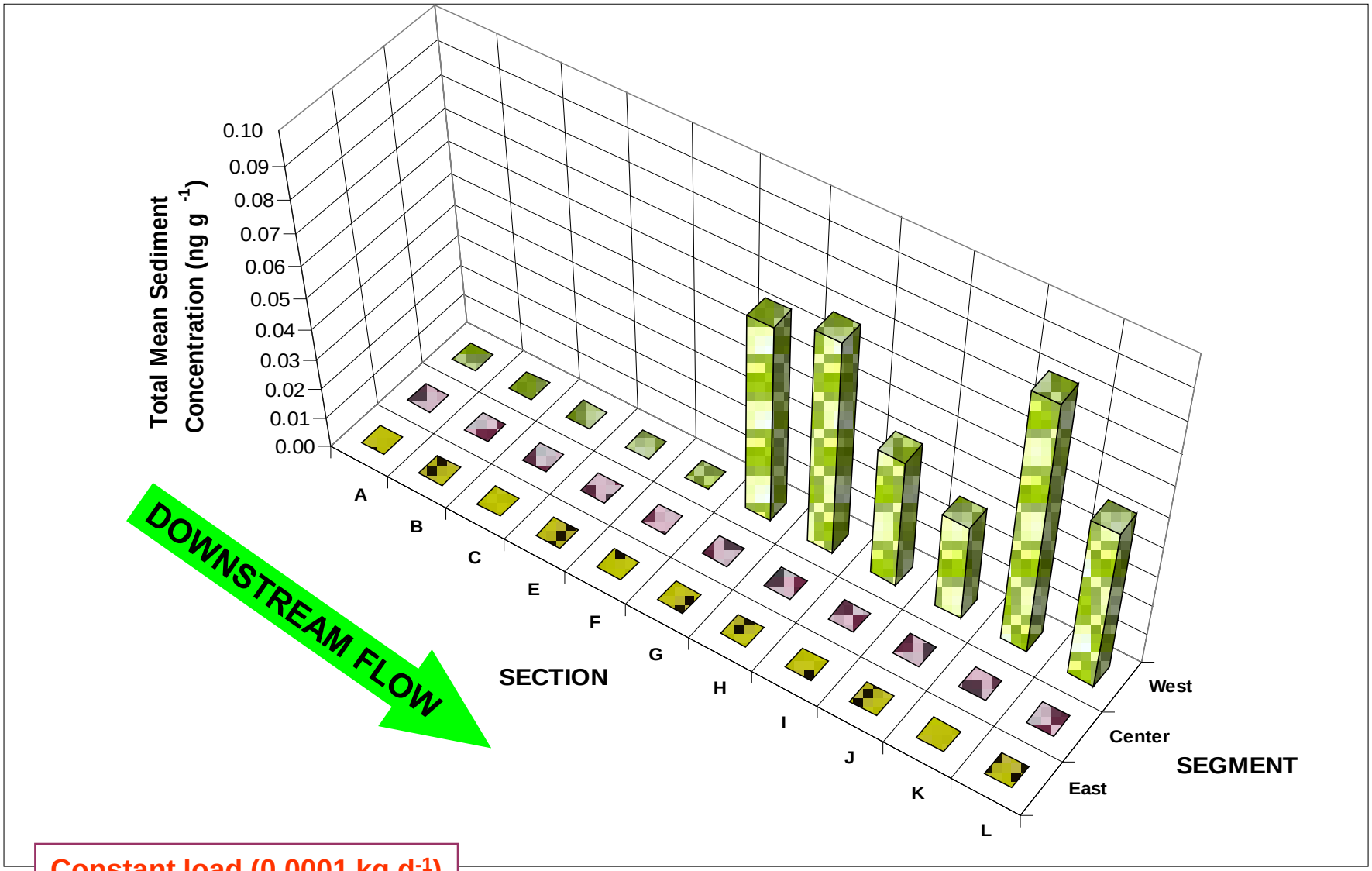
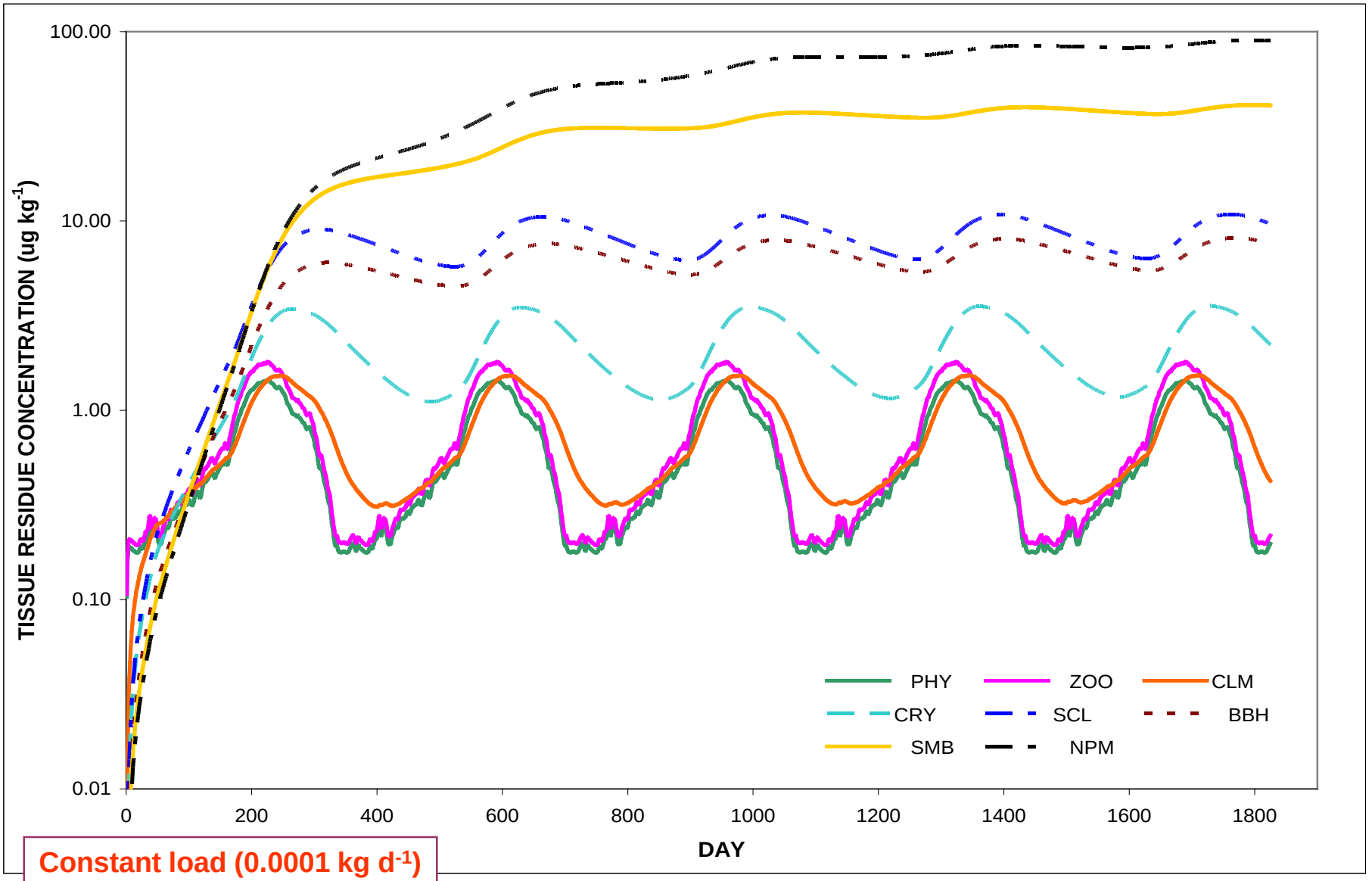


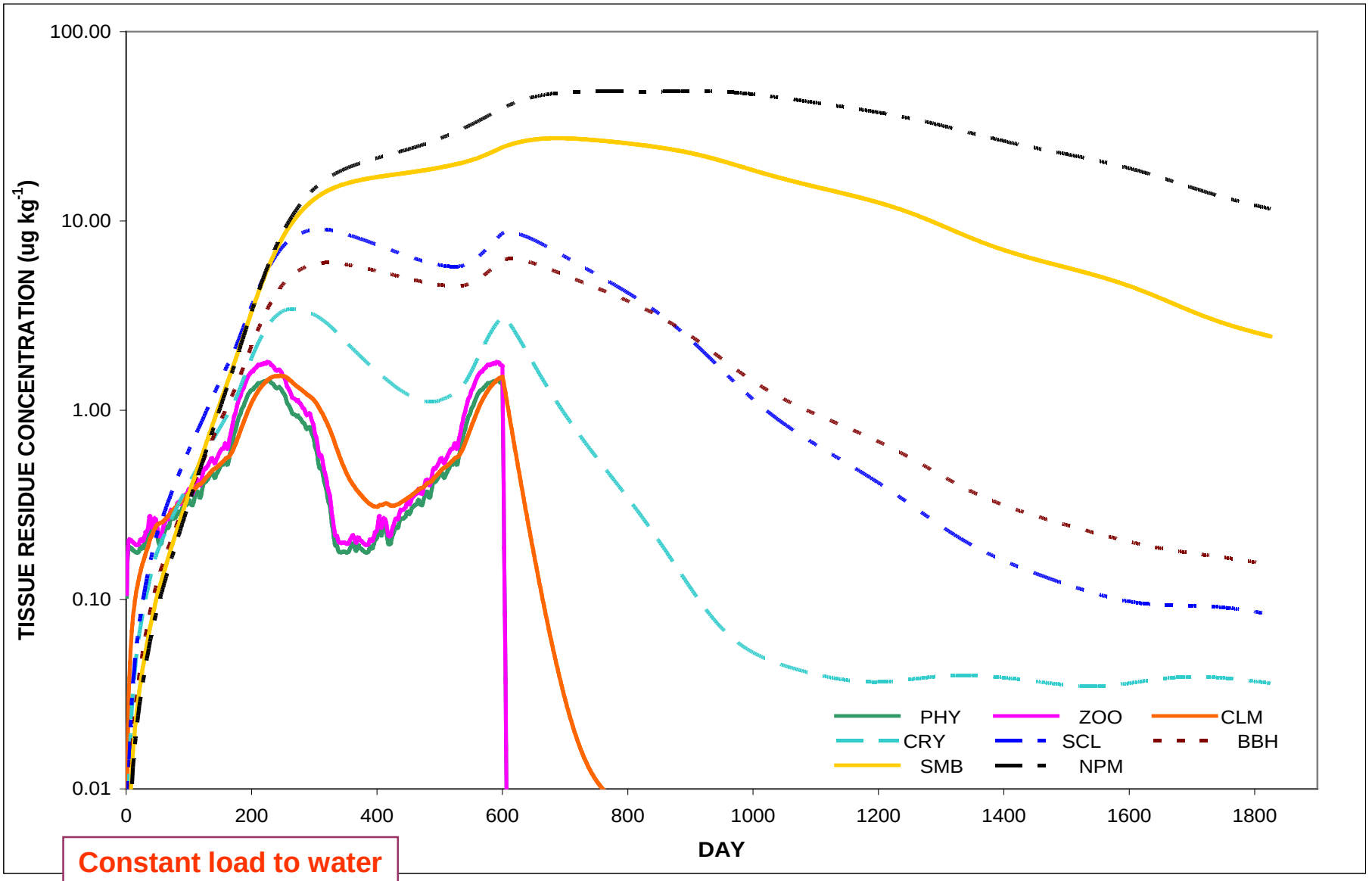
Constant load (0.0001 kg d^{-1}) to water in segment 16

PCB-118 tissue residues over time (baseline)



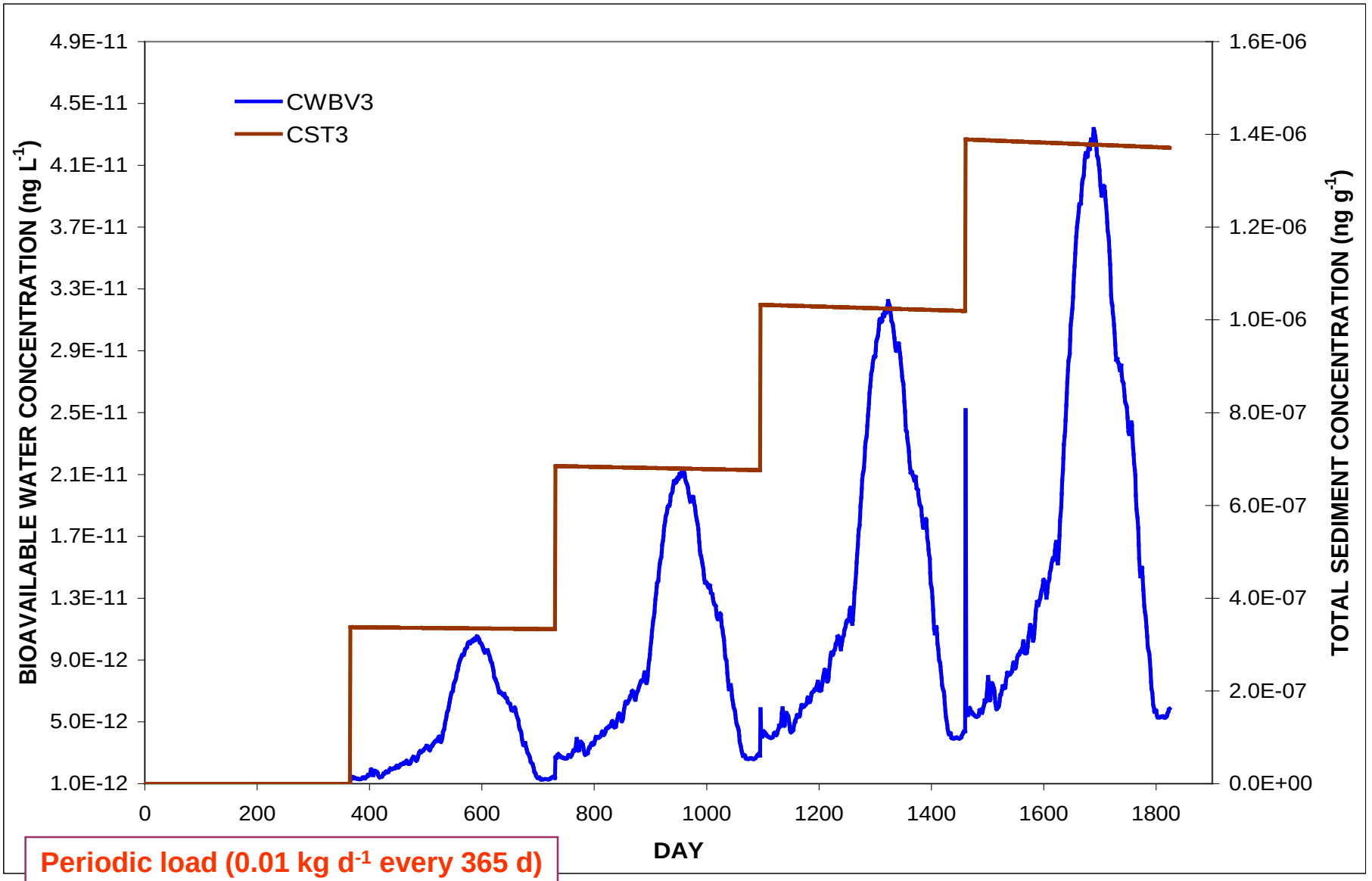
Constant load (0.0001 kg d^{-1}) to water in segments 1,2,3

PCB-118 tissue residues over time (post-remedy)



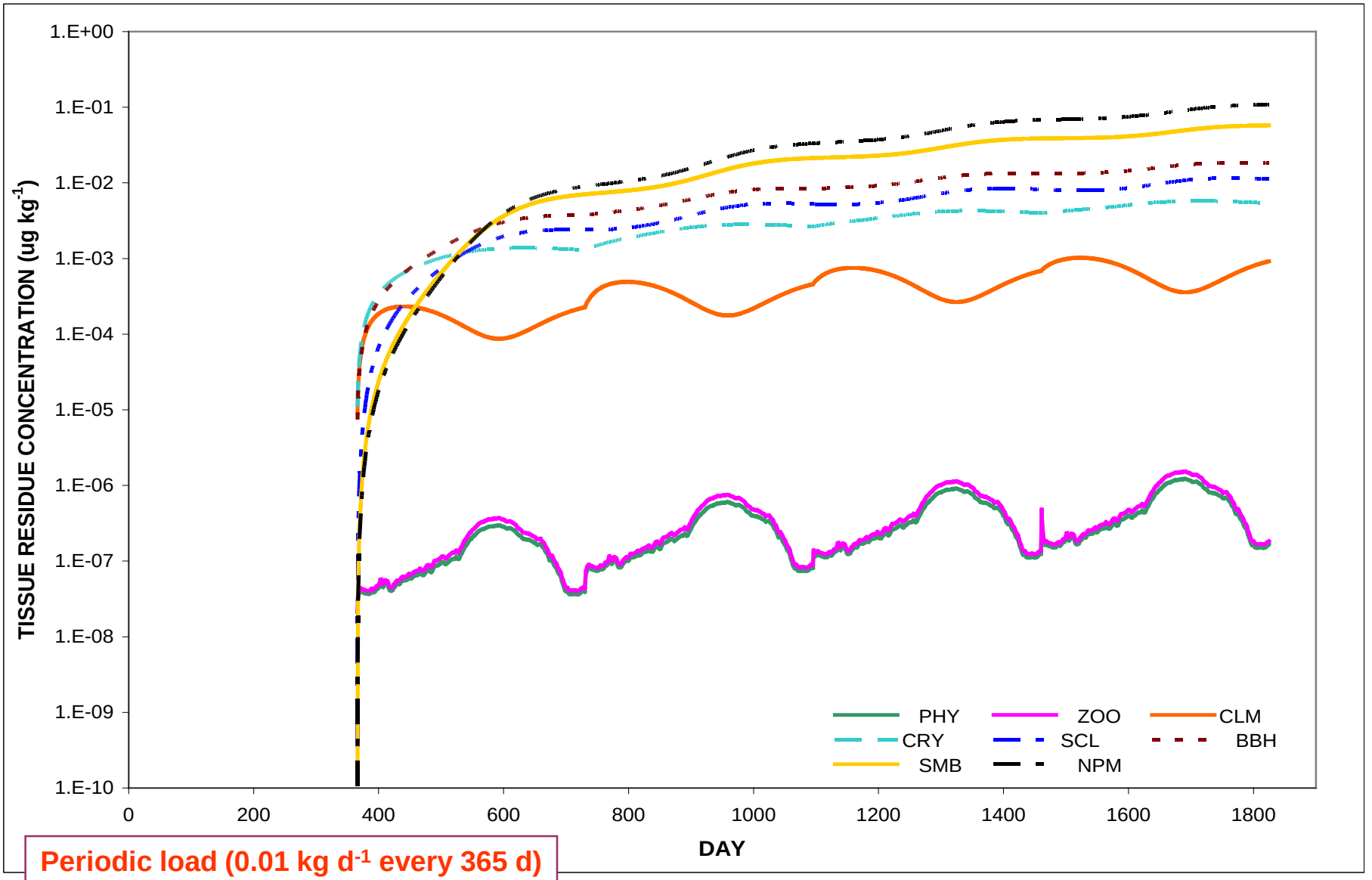
Constant load to water ceases at *t* = 600 d

Changes in water & sediment concentration (periodic)



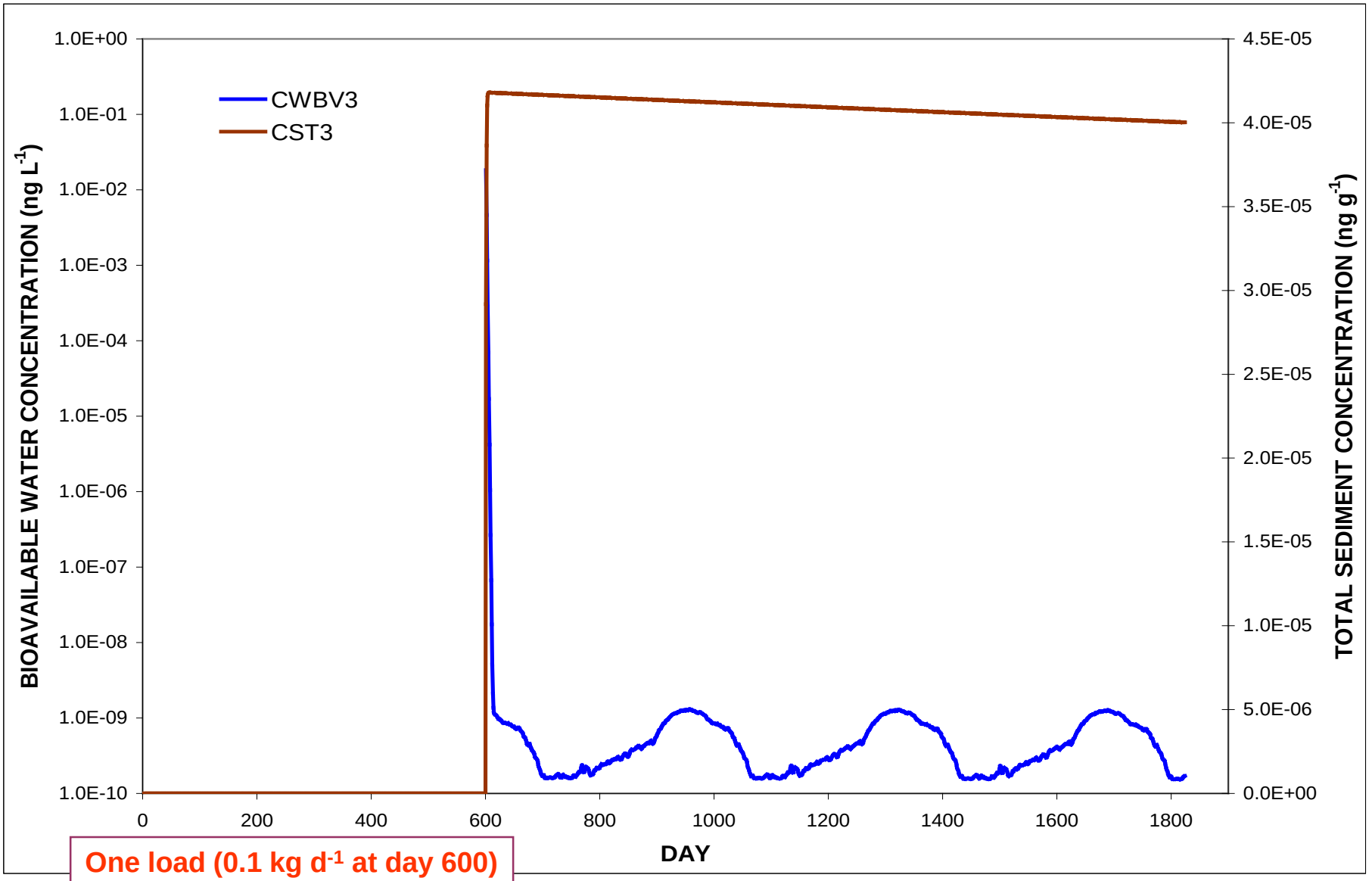
Periodic load (0.01 kg d^{-1} every 365 d) to water in segments 1,2,3

PCB-118 tissue residues over time (periodic)



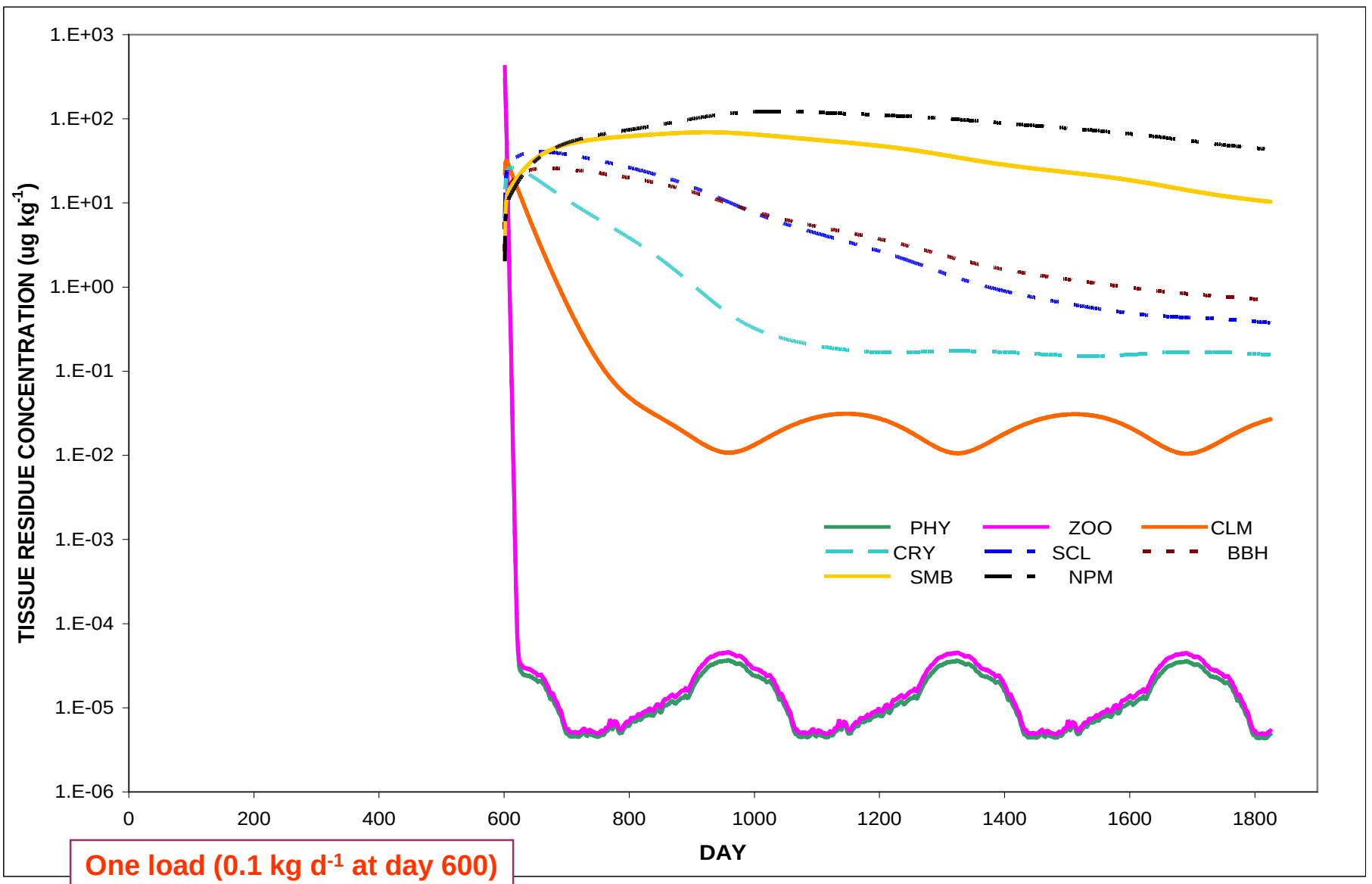
Periodic load (0.01 kg d^{-1} every 365 d) to water in segments 1,2,3

Changes in water & sediment concentration (one load)



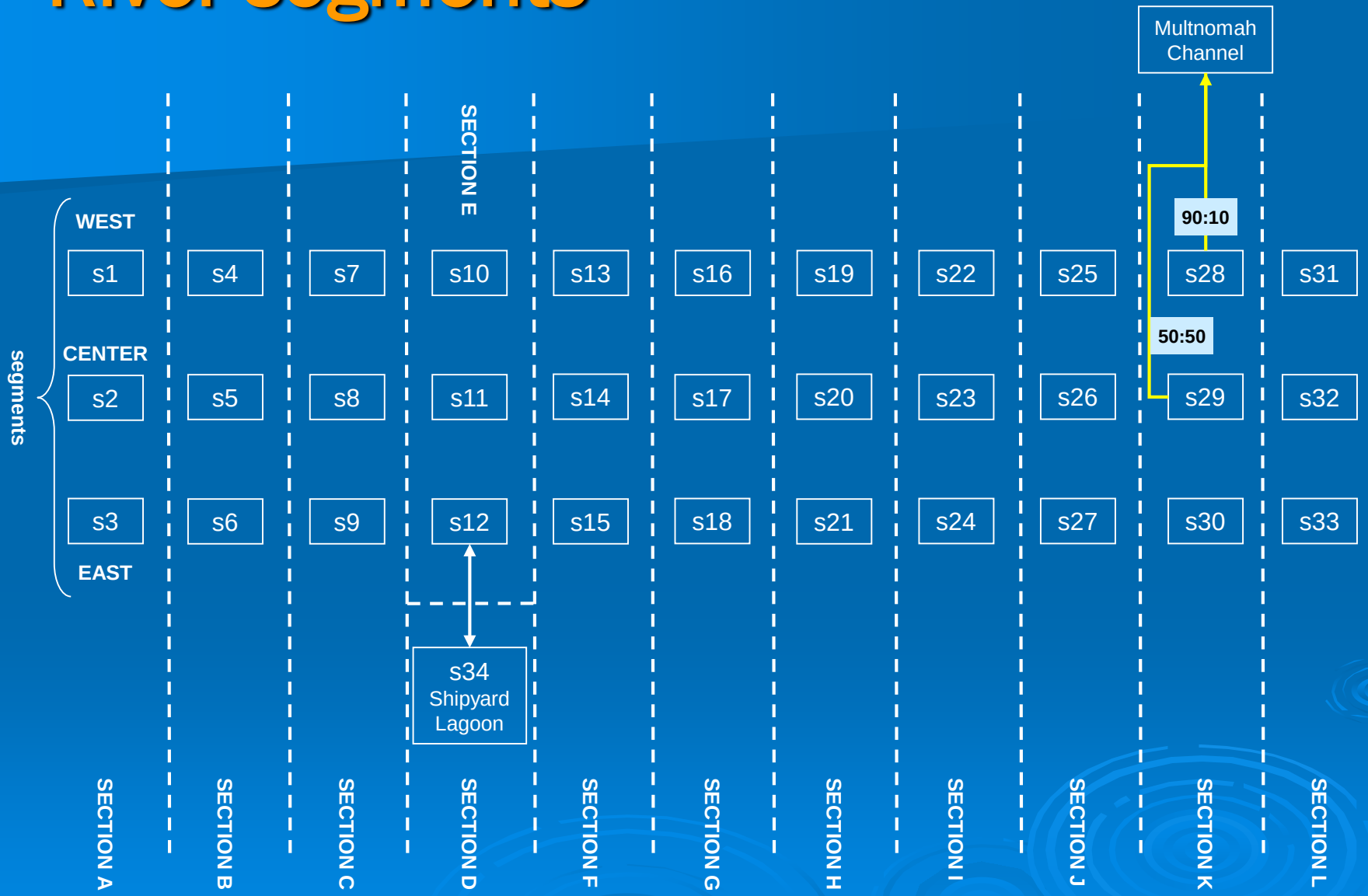
One load (0.1 kg d^{-1} at day 600) to water in segments 1,2,3

PCB-118 tissue residues over time (one load)



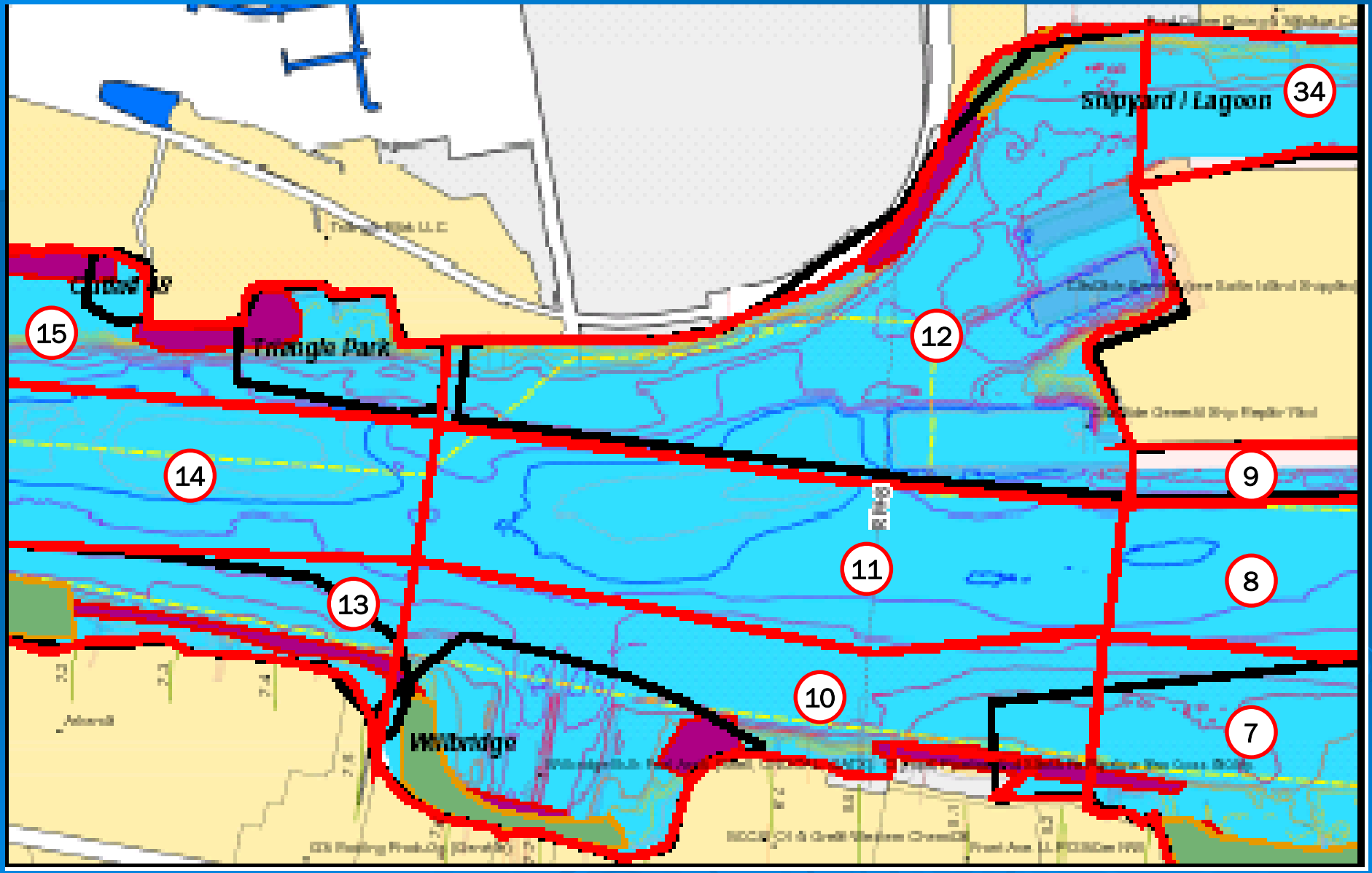
One load (0.1 kg d^{-1} at day 600) to water in segments 1,2,3

River segments

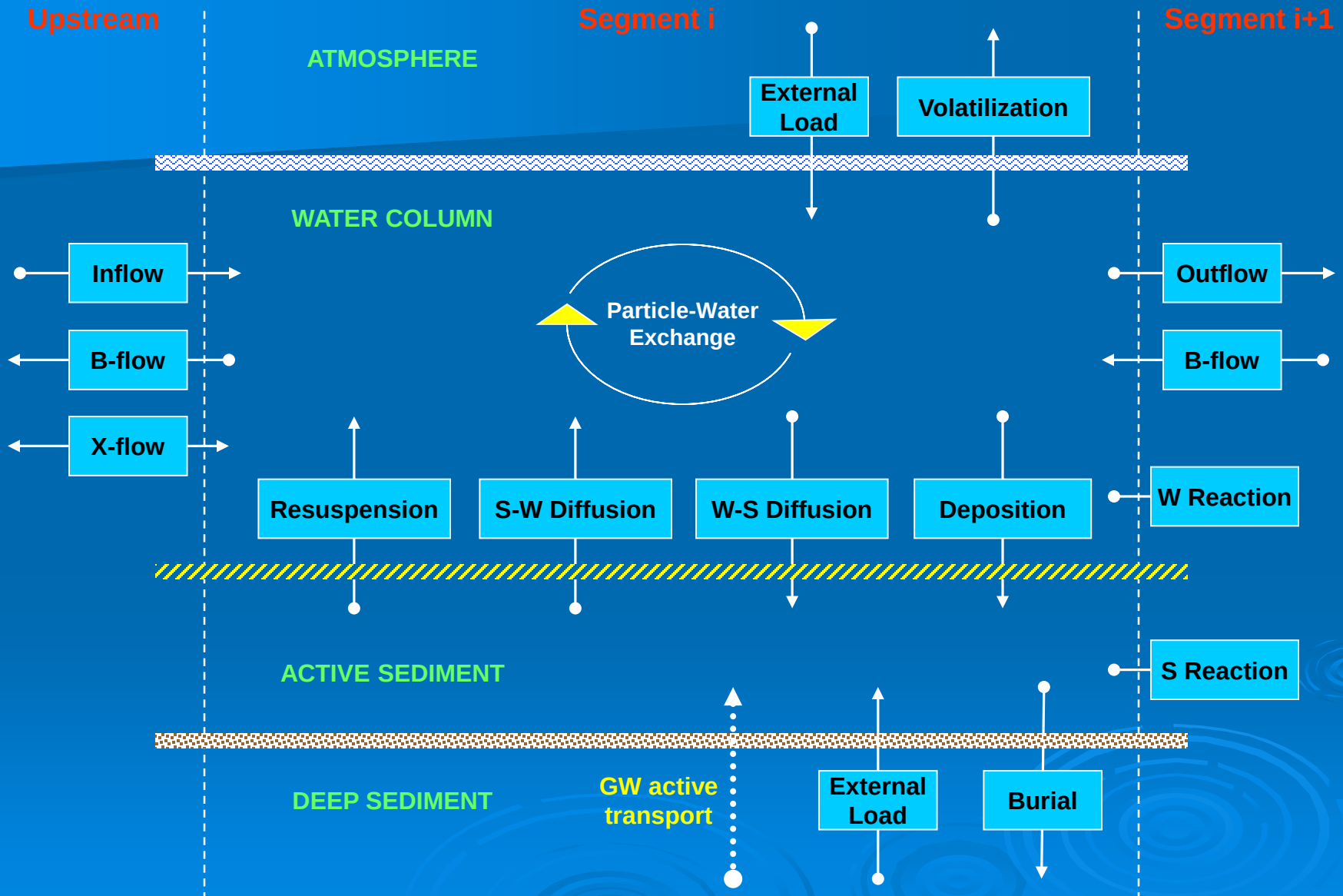


Technical Briefing (May 2006)

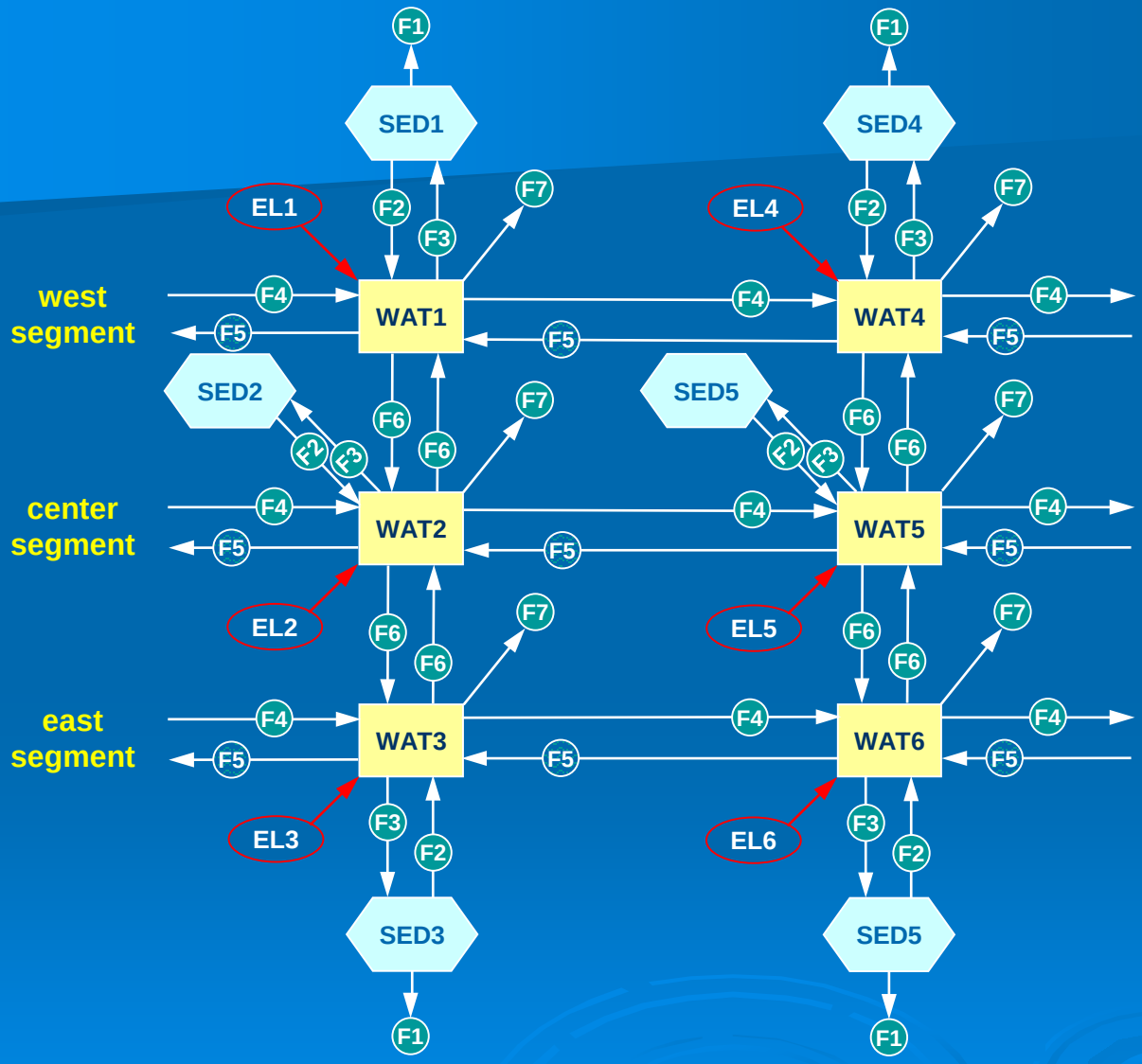
Segments mapped to the physical river



Transport & fate sub-model for a single river segment



Abiotic sub-model relationships between segments

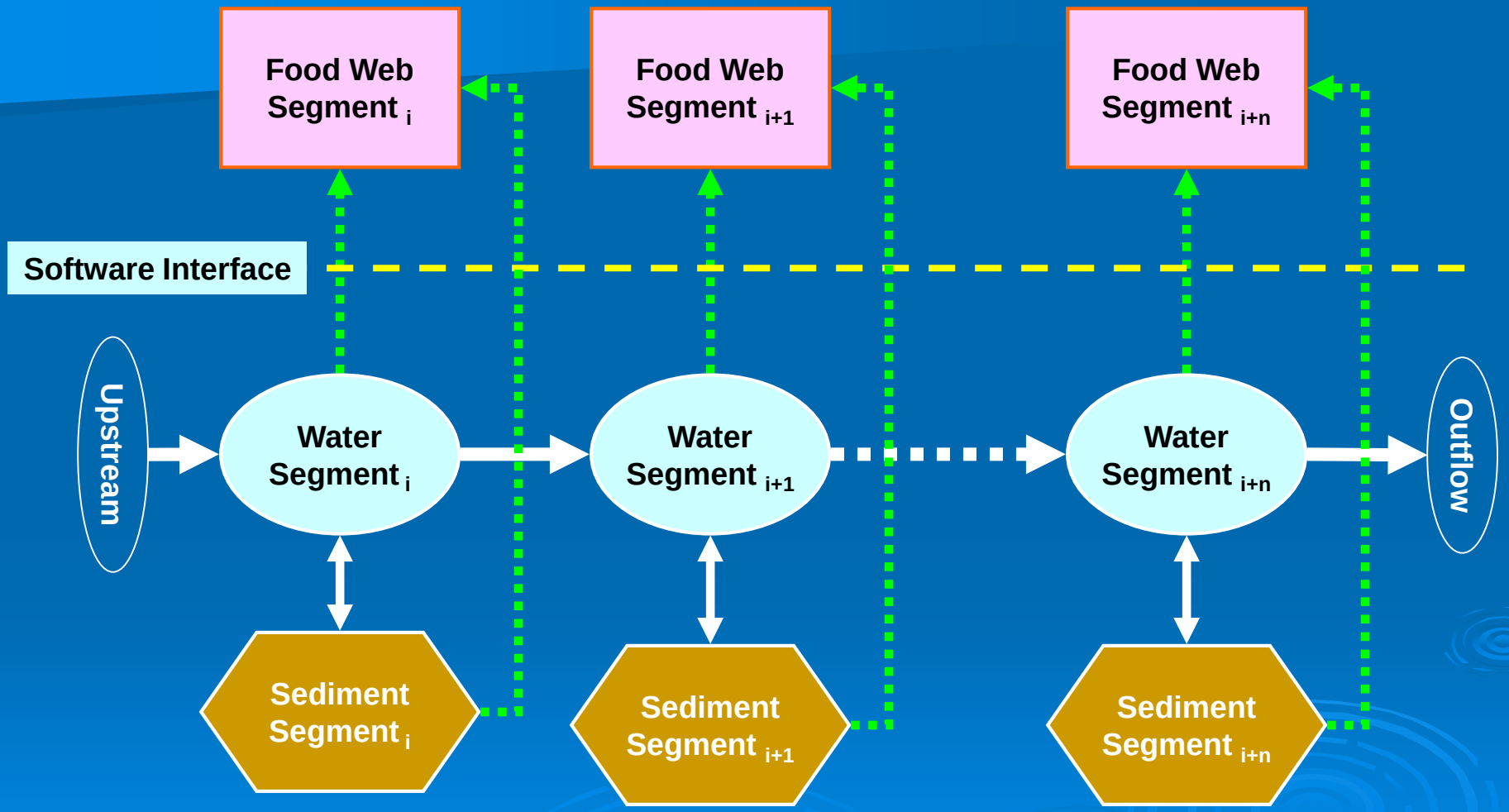


Fluxes

F1 – burial + reaction
F2 – resuspension + diffusion
F3 – deposition + diffusion
F4 – downstream flow
F5 – back-flow
F6 – cross-flow
F7 – volatilization + reaction

Sub-model linkages over multiple segments

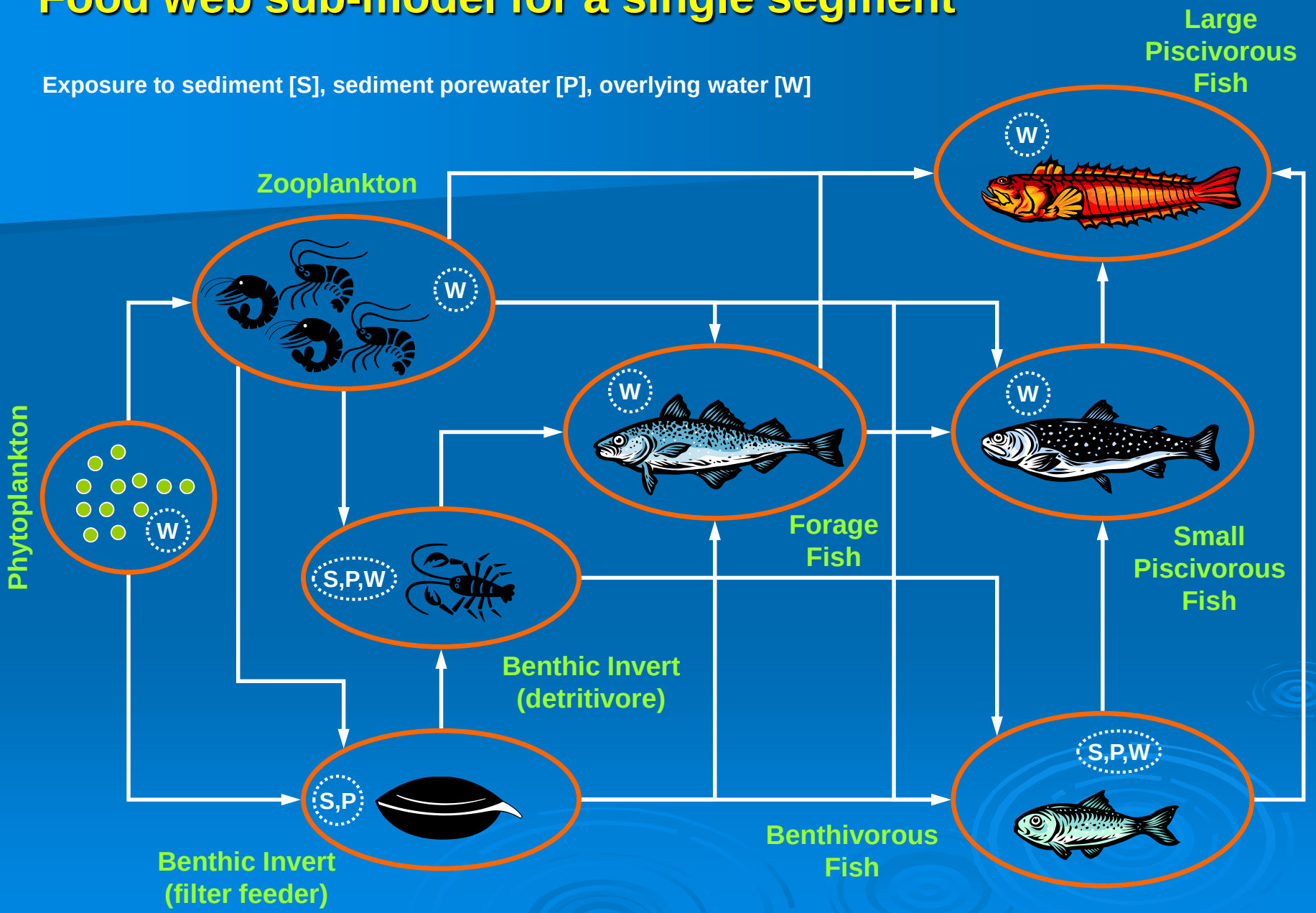
FOOD WEB (BIOTIC) SUB-MODEL



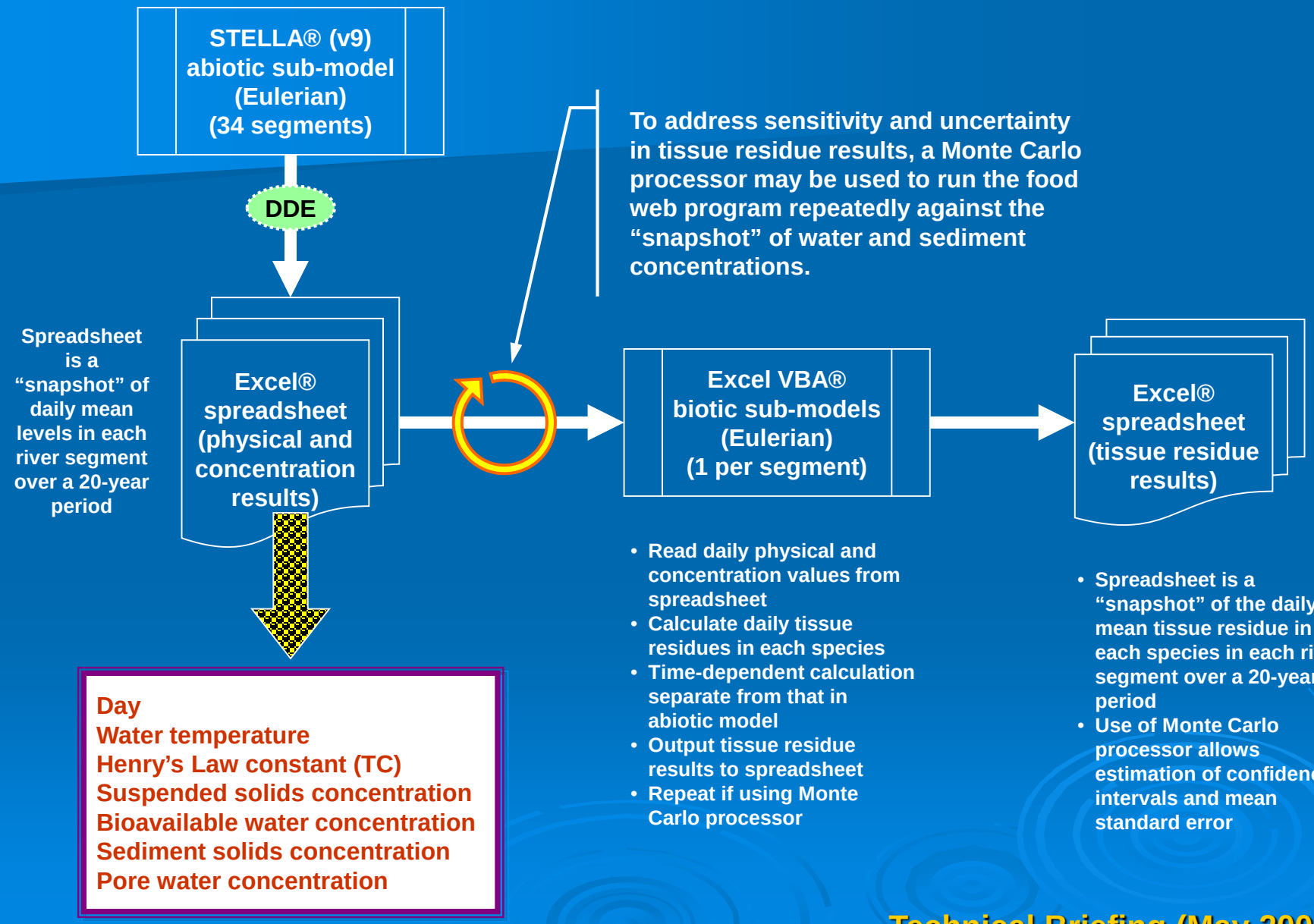
TRANSPORT & FATE (ABIOTIC) SUB-MODEL

Food web sub-model for a single segment

Exposure to sediment [S], sediment porewater [P], overlying water [W]



Data flow and manipulation between sub-models



Contaminants

- POLYCYCLIC AROMATIC HYDROCARBONS
  - Naphthalene
  - Phenanthrene
  - Fluoranthrene
  - Benz(a)anthracene
  - Benzo(b)fluoranthene
  - Dibenz(a,h)anthracene
  - Benzo(ghi)perylene
- METALS
  - Mercury (methylmercury)
  - Arsenic
  - Other
- POLYCHLORINATED BIPHENYLS
  - PCB 18
  - PCB 66
  - **PCB 118**
  - PCB 153
  - PCB 194
- DIOXINS
  - TCDD, PCDD, HCDD
- PESTICIDES
  - DDT
  - DDE
  - DDD

Most sensitive parameters

- ~ Henry's Law constant
- ~ Octanol-water partition coefficient
- Water temperature
- ~ River flow rate
- Active sediment depth
- Concentration of solids in sediment
- Density of particles (suspended) in water
- Sediment solids burial rate
- ~ Bioavailable concentration in water (+ related terms)
- Water content fraction of organism (~ lipids)
- Dietary fraction(s)